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SOFTWARE FOR THE ELECTRICAL CHARACTERIZATION OF CERAMICS USING AN APPLE CONTROLLER AND A HEWLETT-PACKARD 4192A IMPEDANCE ANALYSER

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by

T.A. Wheat and A. Ahmad*

ABSTRACT

The operation of CANMET-developed software for the control of a Hewlett-Packard 4192A impedance analyser is described. Although controllable from its front panel, this instrument is supplied by the manufacturer with the HP-IB interface allowing it to be remotely operated via an IEEE-488 interface, thereby allowing the aquisition and manipulation of data to be conducted automatically using a controller.

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LOGICIEL POUR LA CARACTÉRISATION ÉLECTRIQUE DES CÉRAMIQUES À L'AIDE D'UNE UNITÉ DE CONTRÔLE APPLE ET D'UN ANALYSEUR D'IMPÉDANCE HEWLETT-PACKARD 4192A

par

T.A. Wheat et A. Ahmed*

RÉSUMÉ

Ce rapport présente une brève description du fonctionnement d'un logiciel mis au point au CANMET dans le but de servir au contrôle d'un analyseur d'impédance Hewlett-Packard 4192A. Bien qu'on puisse le contrôler par son tableau avant, cet appareil est muni d'une interface HP-IB fournie par le fabricant. Cette interface permet de télécommander l'appareil en passant par une interface IEEE-488 et par ce moyen de faire automatiquement l'acquisition et la manipulation des données à l'aide de l'unité de contrôle.

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INTRODUCTION

The assembly of solid-electrolyte-based devices, particularly those having a high added value such as fuel cells, thermo-electric generators and batteries, requires the use of high-quality materials that are free of not only external but internal defects such as laminations, macro-pores and cracks. This, in turn, demands a quality assurance procedure that can be applied under production line conditions and which is capable of automatically detecting and rejecting defective components before they are incorporated into any device. This requirement is also of major importance in many of the advanced applications of structural ceramics that are presently under development in various centres such as high-temperature coatings and components for turbine and diesel engines.

For these reasons, CANMET has been interested in the development of non-destructive testing (NDT) techniques for these and similar applications since 1980. Of the three techniques commonly used in NDT (dye impregnation, X-ray and ultrasonic imaging), only the latter two are applicable to find sub-surface defects that do not intercept the free surface. As the resolution of the X-ray and ultrasonic systems are similar and the latter depends on a ceramic element, it was felt appropriate to develop an NDT ultrasonic system capable of high resolution. For this purpose, it became clear that transducers operating at frequencies higher than those of existing commercially available transducers were required. Consequently, the ability to produce and characterize the electrical ceramics used in these and similar devices is essential.

This report outlines the software written and used in CANMET to characterize electrical ceramics. The software is available on disc from the Technical Information Division of CANMET (1).

SYSTEM REQUIREMENTS

The minimum hardware required to use this program includes an Apple II+/IIe controller, two disc drives and an Apple IEEE-488 Interface Card (2) connected to a Hewlett-Packard 4192A Impedance Analyser. Additional options in order of decreasing importance include a printer with graphics capabilities, software for graphics and data manipulation and a plotter with its appropriate software.

As distributed, the program is written to operate under Apple DOS 3.3, to collect data and save on disc in a format compatible with the commercially available graphics software SCIPLOT (3) and to tabulate the data on an Epson printer with an Epson printer interface card.

It is assumed that the device address of the impedance analyser (variable DA, line 2170 in HP.LF.ANALYSER, Appendix A) is set on the rear DIP switch of the instrument at 17.

DISC FILES AND FORMAT

For simplicity in archiving data, it is assumed that the main program disc operates in drive 1 and that all data, whether being saved or retrieved from

earlier runs, are on the disc in drive 2. All data obtained on a sample are retained on disc as two files and appear in a catalogue of the drive 2 disc as Filename.ID and Filename.DATA files. The former file contains the string information: date of run; type of ceramic and its diameter, thickness and temperature; type of electrode and its diameter; the starting, finishing and step frequency for the scan and any comments whereas the latter file contains only numerical information on the real and imaginary admittances that were obtained.

As distributed, the disc is not copy protected. It contains three operating programs: HP.LF.ANALYSER, CHANGE.DATA.HP and MAX/MIN/Z/.HP, together with a number of data files having the prefix PIEZO-TEST. These latter files, which should be transferred to a second disc and used in drive 2, contain the data obtained in characterizing a piezo-electric ceramic sample by scanning from 100 to 1000 kHz in increments of 1 kHz and which were used to generate the figures and most of the tables given as examples in this report. In copying files from the distributed disc, note that the three operating programs must be kept on the same disc because the main boot program (HP.LF.ANALYSER) may switch to the subordinate programs which are assumed to be on the same drive.

The boot program is so configured that it is tightly matched to the sections of memory used - as a result, it cannot be readily modified. The remaining programs may be altered at will.

In characterizing a sample, the operator first creates and stores the two basic data files (Filename.ID and Filename.DATA) and can print out the raw data (real and imaginary admittance) or the parameters: |Z|, Theta, Capacitance and Dissipation while the raw data are still held in memory. These derived parameters are determined for each frequency during output to the printer; they are not held in memory. Alternatively, any pair of Filename.ID and Filename.DATA files can be recovered from disc and used to create additional disc files that contain the variation of |Z|, C, K, and D with frequency. This allows the variation of the derived parameters with frequency to be presented graphically using commercially available programs (3).

All data files created by this program are sequential and use the same format: the first entry is the number of data points in the file, thereafter, the appropriate number of x,y data pairs are entered. A minor deviation from this scheme occurs for the Filename.DATA file, which also contains the starting frequency and the frequency increment as the penultimate and last datum entered in that file. If all possible files are created, then disc 2 will contain the initial Filename.ID and Filename.DATA files with their derivatives Filename.DATA.Z/FR.HP, Filename.DATA.C/FR.HP, Filename.DATA.K/FR.HP and Filename.DATA.D/FR.HP.

THE PROGRAMS

1. HP.LF.ANALYSER

The program logic is shown in Fig. 1. Essentially, the operator is first presented with two screens that identify the origin of the program and indicate that limited documentation is available from the Technical Information Division of CANMET. Thereafter, a selection is made of either: 1. running the impedance analyser to collect new data; 2. retrieving previously stored data from the

disc; or 3. running CHANGE.DATA.HP to modify previously stored data and create the Filename.DATA.Z/FR.HP, etc., files.

Assuming the operator first selected option 1, and entered the following information about the sample:

```
Ceramic - Type:  ABC/123
Diameter (cm)    1.95
Thickness (cm)   0.17
Temperature      24

Electrode - Type Silver paint
Diameter (cm)    1.95

Comments:  Test run of program - note that this comment string can have up
           to 80 characters.
```

they would then be presented with a second screen:

```
Starting frequency (kHz)   100
Stopping frequency (kHz)   1000
Step frequency     (kHz)   1
```

and warned to make sure the cell, etc., is connected before continuing. Thereafter, the analyser would scan the frequency range and pass the real and imaginary admittance values into an array in memory. At the completion of the scan, the operator may view the actual data obtained on the screen (Control-S to toggle on and off output to the screen), then take the option of saving the data on disc. At this point, the disc may be catalogued and any files deleted prior to saving the information in memory. When saved, the information above is saved in the Filename.ID file and the admittance data in the Filename.DATA file. Thereafter, the operator can either run the analyser again, search the data for maxima and minima (Run MAX/MIN/Z.HP, i.e., find the resonance and anti-resonance frequencies), or move to the SCIPLOT graphics routine.

Assuming the option to run again is taken, this returns the operator to the begining of the program to allow selection of either getting further new data, or recovering previously stored data and outputing on the printer in either raw (Fig. 2 - real and imaginary admittance) or derived (Fig. 3 - |Z|, C, K, and D) form or converting the data obtained into files for later use with SCIPLOT (Running CHANGE.DATA.HP).

The program listing is given in Appendix A.

2. CHANGE.DATA.HP

The purpose of this sub-program is to recover the essential information from the initial *.ID and *.DATA files and to write the information back to disc in up to four files having the general name *.DATA.X/FR.HP where X= Z, C, K, and D for the variation with frequency of impedance, capacitance, dielectric constant and dissipation factor respectively. The assumptions used in calculating the various parameters are:

$$|Z| = (Z'^2 + Z''^2)^{0.5} \qquad (1)$$

$$C = -1/\omega Z'' \quad \text{where } \omega = 2\pi \text{ frequency} \qquad (2)$$

$$K = 14.38\ C\ t/d^2 \qquad (3)$$

$$D = Z'/|Z''| \qquad (4)$$

where Z' and Z'' are the real and imaginary impedance. The factor in equation (3) arises from the assumption that circular samples are used and that the capacitance is given in picoFarads (10^{-12} F):

$$C = \varepsilon_r \varepsilon' A/t$$

where ε is the permittivity of the sample and ε' of free space (8.854×10^{-12} Farads/m) and d and t are the diameter and thickness in cm. Hence, the relative permittivity (ε/ε' - dielectric constant K) is $(C\ t/d^2) \cdot 4/\varepsilon' \Pi$. When C is in pF, $4/\varepsilon' \Pi$ is 14.38.

The program listing is given in Appendix B.

3. MAX/MIN/Z/.HP

The purpose of this routine is to search the data array for the points of resonance by noting those frequencies at which the slope of a plot of |Z| vs frequency changes sign. Unfortunately, this is complicated by the occurrence of noise in the spectrum so that a simple search for a change in slope also returns spurious data, as shown in part (A) of Fig. 4 where a total of 20 frequencies are noted where this occurs. To avoid this the routine accepts, as valid resonance points, only those parts of the spectrum where the slope is greater than some arbitary value entered by the user and the slope does not change sign over five frequency intervals on either side of the maximum or minimum found. In that way, any small but sharp spikes characteristic of noise tend to be rejected.

In practice, the user keeps increasing the threshold slope until all the minor changes in |Z| are eliminated and only values with nominally constant differences between them are returned by the program. At that point, the operator has the opportunity to list the data on the printer. Typical examples where only the frequencies occurring in the spectrum at points where the slope exceeds the arbitary threshold values of 0.1 and 0.13 are shown in Fig. 4B.

It can be seen that the data returned are not fully discriminated at the higher slope. Attempts to incorporate the high frequency resonance at 925 and 932 kHz by progressively lowering the slope also return the spurious values of 430 and 431 kHz. However, although not completely rigorous, this routine drastically reduces the data - in this example, down from 900 data pairs to five - and directs the user to only these frequencies for rechecking for resonance.

The program is listed in Appendix C.

GRAPHICAL PRESENTATION OF DATA

Figures 5 and 6 were obtained using the data files created by CHANGE.DATA.HP and show the data obtained on the sample ABC/123, some of which are given in Fig. 3. Comparison of the impedance data presented in Fig. 5 shows the need to use log(impedance) so that the resonances at about 700 and 930 kHz can be seen. The apparently anomolous behaviour of the variation of capacitance with frequency shown in Fig. 7A, where negative values of C are found, arises because the sample exhibits strong inductive coupling at resonance. The negative values correspond to an inductive reactance (4).

DISCLAIMER

In this report, reference to several items of commercially available hardware and software is made merely to indicate what has been used in the CANMET labs. It is not intended that reference to these products in any way is an endorsement of those products.

NOTES

1. This software is available on disc from the Department of Energy, Mines and Resources. Contact the Information Officer, Technical Information Division, 555 Booth Street, Ottawa (613) 995-4064.

2. It should be noted that there are various versions of IEEE-488 cards - some are slot dependent and others are not - the difference may be important in a heavily loaded system. In addition, it should be noted that there are versions of interface cards available that purport to fully conform to the IEEE-488 standard. However, experience in assisting other Labs implement the HP-IB via an Apple controller using a Brand X interface has demonstrated that this is not always so.

3. Available from Interactive Microware Inc., P.O. Box 771, State College, Pa 16801, (814) 238-8294. The Epson version of SCIPLOT has been used to plot the data shown in Fig. 5 and 6. Compatible plotter versions operating via either an RS-232 or IEEE-488 interface are also available.

4. W.G. Cady, "Piezoelectricity" pub. McGraw-Hill, N.Y., p327; 1946.

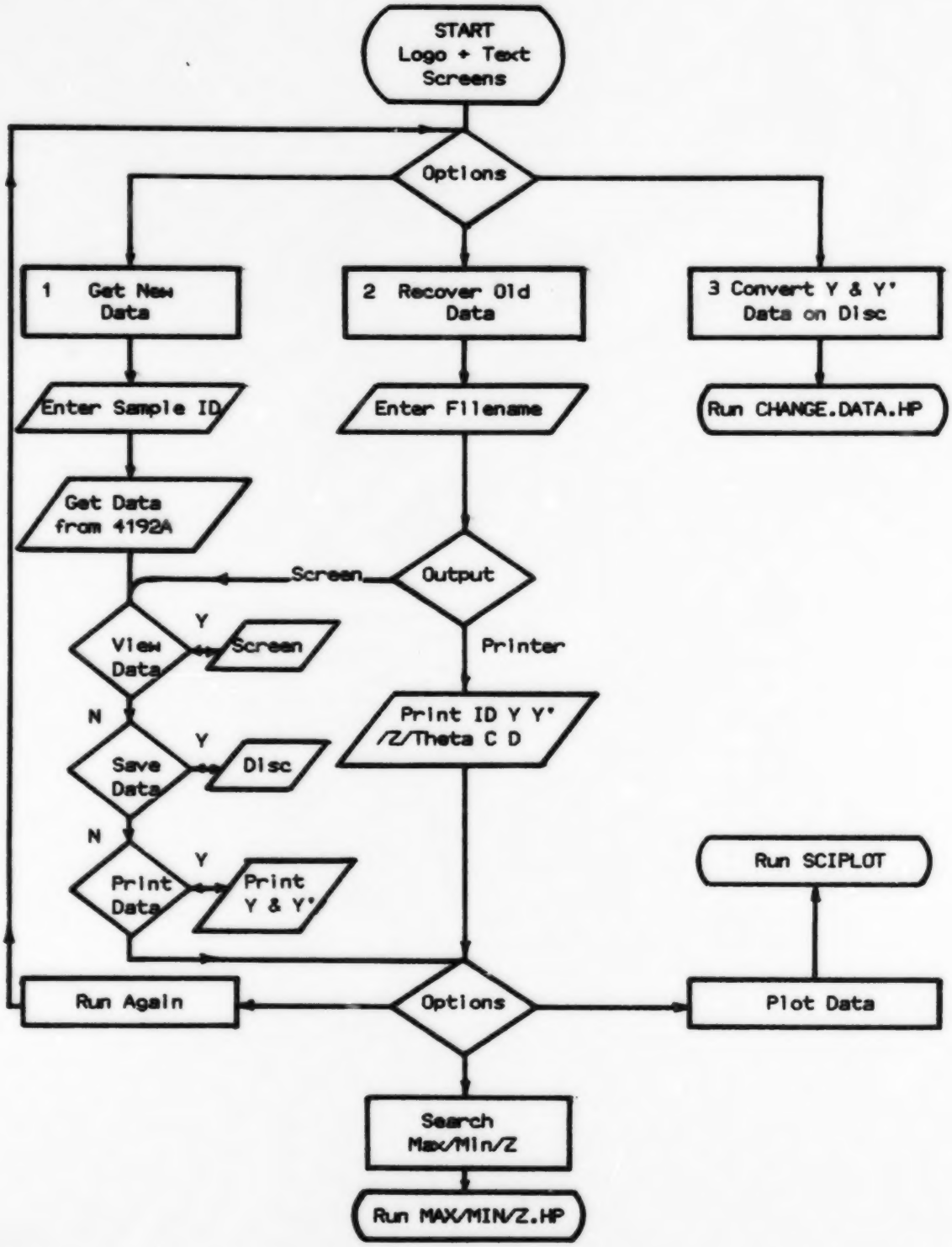


Fig. 1 - Flow sheet for the program HP.LF.ANALYSER

File name: PIEZO-TEST/1

7.8E-07	4.686E-05
1.64E-06	9.31400001E-05
2.5E-06	1.395E-04
3.5E-06	1.859E-04
4.5E-06	2.33E-04
5.5E-06	2.809E-04
6.6E-06	3.299E-04
7.7E-06	3.804E-04
8.9E-06	4.335E-04
1.02E-05	4.902E-04
1.16E-05	5.522E-04
1.34E-05	6.228E-04
1.57E-05	7.103E-04
1.94E-05	8.316E-04
2.84E-05	1.0454E-03
8E-05	1.7E-03
4.15E-04	-2.875E-03
2.651E-05	-1.032E-05
2.25E-05	3.53E-04
1.54E-05	5.076E-04
1.83E-05	6.059E-04
1.73E-05	6.869E-04
1.86E-05	7.538E-04
1.98E-05	8.132E-04
2.11E-05	8.687E-04
2.19E-05	9.203E-04
2.38E-05	9.707E-04
2.47E-05	1.0197E-03
2.51E-05	1.0671E-03
2.71E-05	1.1145E-03
10	10

Fig. 2 - Sample printout of raw admittance data obtained on sample ABC/123 over the frequency range 10-300 kHz in increments of 10 kHz. Note the value of 10 as the penultimate and last datum in the file, which correspond to the starting and incremental frequency (in kHz) used in this scan.

Sept 1985

CERAMIC MATERIAL

TYPE: ABC/123
THICKNESS: 0.17
DIAMETER: 1.95
SAMPLE TEMPERATURE: 24

ELECTRODE

TYPE: SILVER PAINT
DIAMETER: 1.95

SCANNED FROM 100 kHz TO 1000 kHz IN INCREMENTAL STEPS OF 1 kHZ

Trial run of program - note that this comment string can have up to 255 characters

Frequency kHz	Real Adm mS	Imag Adm mS	/Z/ kOhms	Theta Degrees	Capacitance pF	Dissipation
100	7.6E-06	4.9E-04	2040.570	89.11140	779.8592	.0155102
101	7.4E-06	4.96E-04	2015.904	89.14524	781.5926	.0149197
102	7.4E-06	5.02E-04	1991.815	89.15546	783.2919	.0147419
103	7.2E-06	5.08E-04	1968.306	89.18798	784.9583	.0141772
104	7.2E-06	5.14E-04	1944.956	89.19762	786.7457	.0140050
105	7.1E-06	5.2E-04	1921.419	89.21834	788.8022	.0136433
106	7.5E-06	5.27E-04	1899.142	89.19387	790.5196	.0142450
980	1.49E-04	3.78E-03	264.2751	87.74328	614.0457	.0394075
981	1.59E-04	3.79E-03	263.5509	87.57854	615.0422	.0419414
982	1.71E-04	3.8E-03	263.0991	87.42139	615.3883	.0450355
983	1.86E-04	3.8E-03	263.0503	87.19554	614.7622	.0489869
984	1.97E-04	3.79E-03	263.6352	87.02293	612.6818	.0520063
985	2E-04	3.78E-03	264.5296	86.96729	609.9593	.0529901
986	1.94E-04	3.76E-03	265.4633	87.04796	607.2422	.0515683
987	1.82E-04	3.75E-03	266.0700	87.22438	605.3370	.0484816
988	1.67E-04	3.75E-03	266.1193	87.45282	604.7243	.0444859
989	1.54E-04	3.76E-03	265.8758	87.65337	604.7566	.0409792
990	1.44E-04	3.77E-03	265.4101	87.80967	605.2710	.0382479
991	1.35E-04	3.77E-03	265.0118	87.94971	605.6239	.0357995
992	1.26E-04	3.78E-03	264.4733	88.09034	606.2969	.0333421
993	1.17E-04	3.79E-03	263.7961	88.23133	607.2891	.0308788
994	1.09E-04	3.8E-03	263.0497	88.35696	608.4394	.0286842
995	1.04E-04	3.81E-03	262.2319	88.43722	609.7473	.0272822
996	1E-04	3.82E-03	261.4169	88.50202	611.0527	.0261506
997	9.7E-05	3.83E-03	260.6728	88.55110	612.1959	.0252933
998	9.5E-05	3.85E-03	259.8635	88.58579	613.4760	.0246945
999	9.3E-05	3.86E-03	259.1263	88.61910	614.6344	.0241057
1000	9.3E-05	3.87E-03	258.4568	88.62267	615.6113	.0240434

File Name: PIEZO-TEST

Fig. 3 - Example of printout obtained when the sample identification and data on the impedance vector (/Z/), phase angle (theta), capacitance (C) and dissipation (D) are required. Only a part of the total data obtained is shown.

POINTS OF CHANGE OF SLOPE IN TEMP(*)

ARRAY #	Freq
69	168
81	180
108	207
109	208
312	411
314	413
331	430
332	431
346	445
351	450
470	569
472	571
596	695
602	701
797	896
799	898
826	925
833	932
884	983
889	988

LISTING A

FREQUENCIES WHERE A CHANGE OF SIGN IN SLOPE OCCURS
AND THE SLOPE IS GREATER THAN 0.13

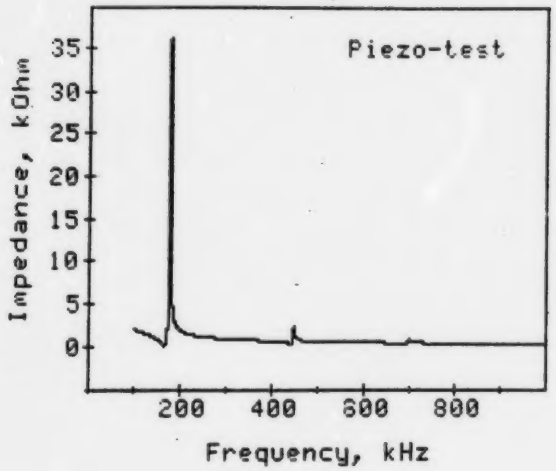
Z	MIN	MAX
2	168	180
10	445	450
14	695	701

LISTINGS B

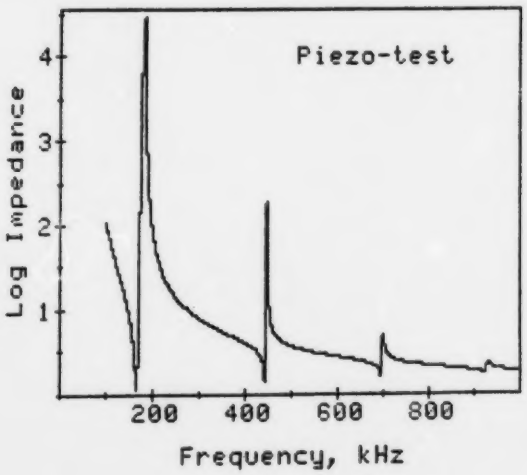
FREQUENCIES WHERE A CHANGE OF SIGN IN SLOPE OCCURS
AND THE SLOPE IS GREATER THAN 0.1

Z	MIN	MAX
2	168	180
10	445	450
14	695	701
18	925	932

Fig. 4 - Example of data produced by the program MIN/MAX/Z/.HP, which finds all occurrences of a change of slope in the impedance-frequency data (listing A) and then discriminates to find the resonant-antiresonant frequencies (listings B).

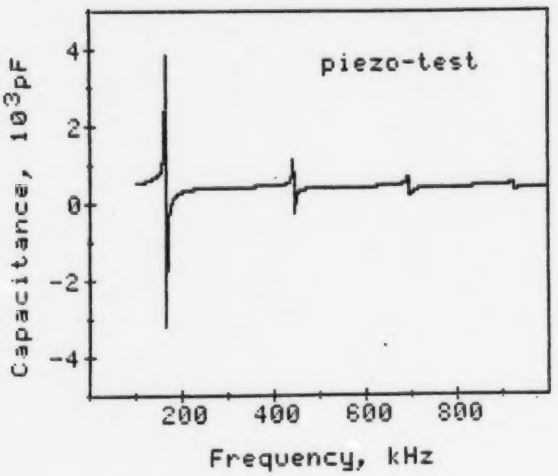


(A)

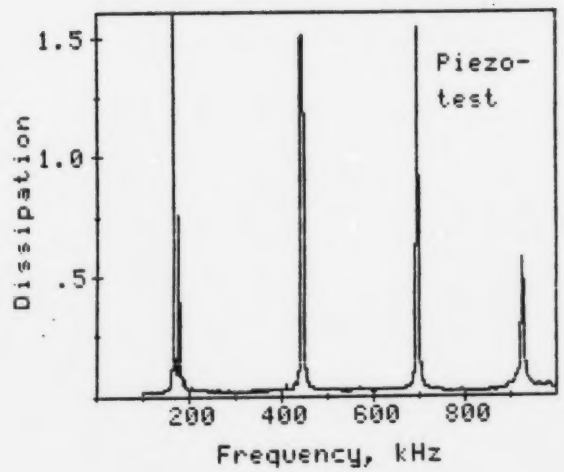


(B)

Fig. 5 - Variation of impedance with frequency plotted using a linear (A) and logarithmic (B) scale for impedance.



(A)



(B)

Fig. 6 - Variation of capacitance (A) and dissipation (B) of sample ABC/123 with frequency.

APPENDIX A

Basic Listing of the Program HP.LF.ANALYSER

```
10  REM  *** HP LF ANALYSER.HP ***
20  REM
30  REM
40  ONERR  GOTO 2570
50  CLEAR : DIM D(2000),A$(15): REM  DIMENSION ARRAYS FOR DATA D(*) & TOMB
     STONE INFO A$(*)
60 D$ =  CHR$ (4):T$ =  CHR$ (26): REM CTRL-D FOR DOS & CTRL-Z as terminat
    or for IEEE
70  DATA 24,144,5,36,55,80,184,56: REM IEEE CARD INFO - LINE 1960
75 :
80 :
90  REM  *** OPTIONS ***
100 :
105 :
110  HOME : HTAB 13: INVERSE : PRINT "SELECT OPTIONS": VTAB 6: HTAB 6: NORMAL
     : PRINT "1  RUN THE HP LF ANALYSER": VTAB 8: HTAB 12: PRINT "- OBTAIN
      THE DATA"
120  HTAB 12: PRINT "- SAVE ON DISC": VTAB 12: HTAB 6: PRINT "2  RECOVER D
     ATA FROM DISC": VTAB 14: HTAB 12: PRINT "- READ THE .DATA/.ID FILES":
      HTAB 12: PRINT "- VIEW THE RAW DATA": HTAB 12: PRINT "- PRINT Z,Thet
     a,C & D vs Freq"
130  PRINT : HTAB 6: PRINT "3  CONVERT DISC ADMITTANCE DATA": PRINT : HTAB
     12: PRINT "- WRITE NEW DISC FILES FOR": VTAB 22: HTAB 14: PRINT "Z,Th
     eta,C etc"
140  VTAB 24: HTAB 25: PRINT "WHICH ? ";: GET A$:A =  VAL (A$): IF A = 1 GOTO
     190
150  IF A = 2 GOTO 1050
160  IF A = 3 GOTO 180
170  GOTO 110
180  PRINT : PRINT D$;"RUN CHANGE.DATA.HP,D1": REM  NEED ONE PRINT STATEME
     NT BEFORE ?D$ TO GET DOS TO WORK
190 :
195 :
200  REM  *** ENTER SAMPLE ID ETC ***
205 :
210 :
220  HOME : HTAB 9: INVERSE : PRINT "EXPERIMENTAL CONDITIONS": VTAB 4: HTAB
     13: PRINT "ENTER SAMPLE ID"
230  NORMAL
240  VTAB 7: HTAB 10: INPUT "CERAMIC  -  Type ";A$(1): HTAB 10: INPUT "DIA
     METER    (cm) ";A$(2)
250  HTAB 10: INPUT "THICKNESS   (cm) ";A$(3): HTAB 10: INPUT "TEMPERATURE
        'C ";A$(4)
260  VTAB 13: HTAB 10: INPUT "ELECTRODE - Type ";A$(5)
270  HTAB 10: INPUT "DIAMETER    (cm) ";A$(6)
280  PRINT : PRINT : HTAB 10: INPUT "DATE ";A$(7)
290  PRINT : PRINT : INPUT "COMMENTS ";A$(8)
300  HOME : VTAB 10: PRINT "If Frequency Increment (FI) is to be a": PRINT
     "decimal e.g., 0.1 or .1, then the Stop": PRINT "Frequency (HF) must
     be one increment": PRINT "higher than the desired Stop Frequency.": PRINT
     : PRINT
310  PRINT "E.g., to scan 0.1 to 1 kHz in steps of": PRINT " 0.1 kHz use a
      Stop Frequency of 1.1": VTAB 22: PRINT "HIT ANY KEY TO CONTINUE ";: GET
     A$
320  HOME : VTAB 10: HTAB 5: INPUT "ENTER START FREQUENCY kHz ";LF: HTAB 1
     0: INPUT "  STOP FREQUENCY kHz ";HF: PRINT : HTAB 12: INPUT "STEP FRE
     QUENCY kHz ";FI
330 A$(9) =  STR$ (LF):A$(10) =  STR$ (HF):A$(11) =  STR$ (FI)
```

```
340 ZZ = 0: PRINT D$;"PR#0": PRINT D$;"IN#0": HOME : VTAB 12: PRINT "CONNE
    CT CELL ...": VTAB 24: INPUT "HIT RETURN TO CONTINUE ";A$: REM  IF Ha
    ve a PRINT/GET statement in place of INPUT/A$ in this line, IEEE WILL
     BOMB!
350 :
360  GOSUB 1960: REM  FIND FIND SLOT HOLDING IEEE CARD
365  IF SL = 0 THEN  GOSUB 2590
367  IF (SL = 0 AND ZZ = 1) THEN 340
370 :
380  GOSUB 2090: REM  READ HP ADMITTANCES/FREQUENCY
390 :
400 :
410  REM  *** VIEW, PRINT, SAVE DATA ***
420 :
430 :
440  PRINT D$;"PR#0": PRINT D$;"IN#0":D(0) = I - 1: HOME : VTAB 8: HTAB 8:
     PRINT "VIEW DATA? Y/N ": GET A$
450  IF A$ = "N" THEN 530
460  IF A$ <  > "Y" THEN 440
470  HOME
480 X1 = 1: FOR N = 1 TO I STEP 2: PRINT D(N).D(N + 1)
490  IF N > 44 * X1 THEN  GOSUB 510
500  NEXT : IF N < 44 * X1 GOTO 520
510  GET A$:X1 = X1 + 1: RETURN
520  VTAB 24: HTAB 8: PRINT "HIT ANY KEY TO CONTINUE ": GET A$
530  HOME : VTAB 10: PRINT "SAVE TO DISC? (Y/N) ... USES DRIVE 2": GET A$
540  IF A$ = "Y" THEN 680
550  HOME : VTAB 10: PRINT "TABULATE THE DATA ON EPSON? Y/N": GET A$
560  IF A$ = "Y" THEN 590
570  IF A$ = "N" THEN 610
580  GOTO 550
590  PRINT : PRINT D$;"PR#1": PRINT  CHR$ (27)"@": PRINT "File name: "FI$:
     PRINT  CHR$ (15) CHR$ (9)"132N" CHR$ (27)"N" CHR$ (6): FOR X = 1 TO
    D(0) STEP 2: PRINT D(X),D(X + 1): NEXT
600  PRINT  CHR$ (12);
610  PRINT : PRINT D$;"PR#0": HOME
620  VTAB 10: HTAB 4: PRINT "WHAT DO YOU WISH TO DO": PRINT : PRINT : HTAB
    12: PRINT "1. RUN AGAIN": HTAB 12: PRINT "2. PLOT DATA": HTAB 12: PRINT
    "3. SEARCH FOR MAX/MIN OF /Z/": PRINT : PRINT : HTAB 12: PRINT "4. EN
    D ": VTAB 22: HTAB 25: PRINT "WHICH ? ":: GET A$
630  IF A$ = "1" THEN 40
640  IF A$ = "2" THEN 1730
650  IF A$ = "3" THEN 675
660  IF A$ = "4" THEN  END
670  GOTO 620
675  PRINT : PRINT D$;"RUN MAX/MIN/Z.HP,D1"
680  VTAB 14: PRINT "CATALOG DRIVE 2? (Y/N) ": GET A$
690  IF A$ = "Y" THEN 710
700  IF A$ = "N" THEN 820
710  PRINT : PRINT D$;"CATALOG,D2"
720  PRINT : PRINT
730  VTAB 24: PRINT "DELETE ANY FILES? (Y/N) ": GET A$: IF A$ = "N" THEN 8
    20: IF A$ <  > "Y" THEN 730: PRINT : PRINT : INPUT "ENTER NAME OF FIL
    E TO DELETE";FI$
740  IF A$ = "N" THEN 820
750  IF A$ <  > "Y" THEN 730
760  PRINT : PRINT : PRINT "ENTER NAME OF FILE TO DELETE": PRINT : INPUT "
    USE FULL NAME (+.DATA/.ID ...)";FI$
770  PRINT : PRINT D$;"UNLOCK";FI$",D2"
780  PRINT : PRINT D$;"DELETE";FI$",D2"
```

```
790  HOME
800  VTAB 10: PRINT "DELETE ANOTHER FILE? (Y/N)": GET A$
810  IF A$ = "Y" THEN 760
820  HOME : VTAB 10: INPUT "ENTER NAME OF FILE TO SAVE ";FI$
830 :
835 :
840  REM  *** SAVE ID FILE ***
845 :
850 :
860  PRINT D$;"OPEN";FI$;".ID,D2"
870  PRINT D$;"WRITE";FI$;".ID"
880  FOR J = 1 TO 11: REM  A$ INFO IN LINES 210-260
890  PRINT A$(J)
900  NEXT J
910  PRINT D$;"CLOSE";FI$;".ID"
920 :
925 :
930  REM  *** SAVE DATA FILE ***
935 :
940 :
950  PRINT D$;"OPEN";FI$;".DATA,D2"
960  PRINT D$;"WRITE";FI$;".DATA"
970  PRINT I + 2: REM PUT # DATA POINTS (I) +2 (LF & FR) IN D(0) IN FILE
980 D(I + 1) = LF:D(I + 2) = FI: REM  Add starting frequency & increment t
    o end of .DATA FILE on disc
990  FOR J = 1 TO I + 2
1000  PRINT D(J)
1010  NEXT J
1020  PRINT  VAL (A$(9)): PRINT  VAL (A$(11)): REM Place the starting freq
    uency and its increment at the end of the .DATA file
1030  PRINT D$;"CLOSE";FI$;".DATA"
1040  GOTO 550
1044 :
1046 :
1050  REM  *** DUMP FREQUENCY.IMPEDANCES,THETA,/Z/,CAPACITANCE AND DISSIPA
    TION WITH TOMBSTONE DATA ON EPSON ***
1055 :
1060 :
1070  HOME : VTAB 10: PRINT "PUT DATA DISK IN DRIVE 2 ... AND HIT ANY KEY
    ": GET A$
1080  HOME : VTAB 10: PRINT "ENTER FILE NAME": VTAB 12: HTAB 5: INPUT "...
     .DATA/.ID NOT NEEDED ";FI$
1090  PRINT D$;"OPEN";FI$".DATA,D2"
1100  PRINT D$;"READ";FI$".DATA"
1110  INPUT D(0): REM  GET # DATA PTS IN FILE
1120  FOR X = 1 TO D(0)
1130  INPUT D(X)
1140  NEXT X
1150  PRINT D$;"CLOSE";FI$;".DATA"
1160  PRINT D$;"OPEN";FI$;".ID"
1170  PRINT D$;"READ";FI$;".ID"
1180  FOR X = 1 TO 11: REM INFO IN LINES 210-260
1190  INPUT A$(X)
1200  NEXT X
1210  PRINT D$;"CLOSE";FI$;".ID"
1220  HOME : PRINT "OUTPUT ON SCREEN OR PRINTER (S/P) ": GET A$:I = D(0) +
    1: REM  SET COUNTER BEFORE READING FILE
1230  IF A$ = "S" THEN 470: IF A$ = "P" THEN 1250: GOTO 1220
1240 :
1245 :
```

```
1250  REM  *** RX-80 PRINTER ROUTINE ***
1255 :
1260 :
1270  REM  A$(*) - TOMBSTONE INFO
1280  REM  D(*)  - DATA IN ARRAY D(0)-# PTS IN ARRAY
1290  PRINT : PRINT D$;"PR#1"
1300  PRINT  CHR$ (27)"@": REM  INITIALIZE PRINTER
1310  PRINT  CHR$ (9); CHR$ (1): PRINT  CHR$ (1)"80N": REM  RE-ASSIGN CHR$
     (9) TO CHR$(1) & USE IT TO SET 80 COLUMNS
1320  PRINT  CHR$ (27)"N" CHR$ (6): REM  SKIP OVER PERFORATION ON RX
1330  PRINT  CHR$ (27);"e"; CHR$ (0); CHR$ (11);: REM     SET TAB STOPS TO
     EVERY 11 SPACES FOR RX-80 PRINTER - P 3-37
1340 HT$ =  CHR$ (9): REM  HORIZONTAL TAB KEY
1350  PRINT  CHR$ (27)"E";: REM  EMPHASIZED PRINT
1360  PRINT HT$;HT$;HT$;HT$;HT$;HT$;A$(7): PRINT : PRINT : REM DATE
1370  PRINT HT$;"CERAMIC MATERIAL";
1380  PRINT HT$;HT$:HT$;"ELECTRODE"
1390  PRINT  CHR$ (27)"F";: REM  CANCELS EMPHASIZED PRINT
1400  PRINT  CHR$ (15);: PRINT  CHR$ (1)"132N": CHR$ (27)"N" CHR$ (6)
1410  PRINT "TYPE: ";A$(1);: PRINT HT$;HT$;"DIAMETER: ";A$(2);
1420  PRINT HT$;HT$;"TYPE: ";A$(5);: PRINT HT$:HT$;"DIAMETER: ";A$(6)
1430  PRINT "THICKNESS: ";A$(3);: PRINT HT$;HT$;"SAMPLE TEMPERATURE: ";A$(
     4): PRINT
1440  PRINT "SCANNED FROM ";A$(9);" kHz TO ";A$(10);" kHz IN INCREMENTAL S
     TEPS OF ";A$(11);" kHZ": PRINT
1450  PRINT A$(8): REM  COMMENTS LINE
1460  PRINT
1470  PRINT "Frequency";HT$;"Real Adm";HT$:"Imag Adm";HT$;"  /Z/  ";HT$:"
     Theta ";HT$;"Capacitance";HT$;"Dissipation"
1480  PRINT "  kHz";HT$;"   mS ";HT$;"   mS ";HT$;"kOhms";HT$;"Degrees";HT
     $;"    pF "
1490  FOR X = 1 TO 125: PRINT "=";: NEXT X
1500  PRINT
1510 I = 0
1520  FOR X = 1 TO D(0) STEP 2
1530 I = I + 1: REM  COUNTER FOR FREQ INCREMENTS
1535  IF  VAL (A$(9)) + (I - 1) *  VAL (A$(11)) >  VAL (A$(10)) THEN  GOTO
     1650
1540  PRINT : PRINT  VAL (A$(9)) + (I - 1) *  VAL (A$(11));: REM  Frequenc
     y
1550  PRINT HT$;:Y = D(X): GOSUB 1830: REM  Y=Real Admittance
1560  PRINT HT$;:Y = D(X + 1): GOSUB 1830: REM  Y=Imaginary Admittance
1570  PRINT HT$;:Y =  SQR (D(X) ^ 2 + D(X + 1) ^ 2):Y = 1 / Y: GOSUB 1830:
     REM  Y=Impedance /Z/
1580  PRINT HT$;:Y =  ATN (D(X + 1) / D(X)) * 57.2957795: GOSUB 1830: REM
     Y=Theta in degrees
1590  IF D(X) = 0 THEN 1640
1592  IF D(X + 1) = 0 THEN 1640
1594  IF  VAL (A$(9)) + (I - 1) *  VAL (A$(11)) >  VAL (A$(10)) THEN  GOTO
     1650
1600 P2 = 6.2831852: REM 2 x Pi
1610  PRINT HT$;:Y = 1E9 * D(X + 1) / (P2 * ( VAL (A$(9)) + (I - 1) *  VAL
     (A$(11)))): GOSUB 1830: REM    Y=Capacitance  (in Picofarads) when Fr
     equency is in kHz
1620  PRINT HT$;:Y =  ABS (D(X) / D(X + 1)): GOSUB 1830: REM Y=Dissipation
      factor
1630  IF X = D(0) - 2 THEN  PRINT
1640  NEXT
1650  PRINT : PRINT : PRINT  CHR$ (27)"E";: PRINT "File Name: ";FI$
1660  PRINT  CHR$ (12);
```

```
1670  PRINT  CHR$ (27)"@": REM  RE-INITIALIZE PRINTER
1680  PRINT D$;"PR#0": PRINT D$;"IN#0": HOME : GOTO 610
1730  HOME : HTAB 8: VTAB 10: PRINT "USE WHICH VERSION OF SCIPLOT?": VTAB
      12: HTAB 8: PRINT "EPSON OR HP-PLOTTER (E/H) ";: GET A$
1740  HOME : PRINT "PUT SCIPLOT DISC IN DRIVE 1": VTAB 12: HTAB 5: PRINT "
      ... MUST HAVE SCIPLOT COMPATIBLE": HTAB 5: PRINT "FILES OF Z,C,K & D
      vs FREQUENCY ON": HTAB 5: PRINT "DRIVE 2 ...": VTAB 23: PRINT "'ESC'
      FOR MAIN MENU": PRINT "ANY OTHER KEY TO CONTINUE ";: GET AA$
1750  IF AA$ =  CHR$ (27) THEN  GOTO 110
1760  IF A$ = "H" THEN  GOTO 1790
1770  IF A$ = "E" THEN  GOTO 1800
1780  GOTO 1740
1790  PRINT : PRINT D$;"RUN SCIPLOT-HP,D1"
1800  PRINT : PRINT D$;"RUN SCIPLOT-EPSON,D1"
1810  IF A$ <  > "H" AND A$ <  > "E" THEN 1730
1820  REM   --- PRINTER SUBROUTINES
1830 E = 0: IF  LEFT$ ( RIGHT$ ( STR$ (Y),4),1) = "E" THEN E = 1
1840 L =  LEN ( STR$ (Y))
1850  IF E = 1 GOTO 1880
1860  IF E = 0 GOTO 1910
1870  RETURN
1880  IF L > 8 THEN  PRINT  INT ( VAL ( LEFT$ ( STR$ (Y),5)) * 100 + .5) /
      100; RIGHT$ ( STR$ (Y),4);: REM  ROUND OFF
1890  IF L =  < 8 THEN  PRINT Y;
1900  RETURN
1910  IF L > 8 THEN  PRINT  LEFT$ ( STR$ (Y),8);
1920  IF L =  < 8 THEN  PRINT Y;
1930  RETURN
1940 :
1950 :
1960  REM *** CHECK FOR AND LOCATE IEEE CARD SLOT ***
1970 :
1980 :
1990  FOR X = 0 TO 7: READ SB%(X): NEXT
1992  RESTORE
2000 SL = 0:IC = 1
2010  FOR XS = 1 TO 7:SL = XS
2020 XA =  - 16384 + 256 * XS
2030  FOR XB = 0 TO 7: IF  PEEK (XA + XB) <  > SB%(XB) THEN SL = 0:XB = 8
2040  NEXT XB: IF SL THEN XS = 8
2050  NEXT XS: IF SL = 0 THEN IC = 0
2060  RETURN
2070 :
2080 :
2090  REM *** HP LF ANALYSER AT ADDRESS 17 FOR ADMITTANCE DATA ***
2100 :
2110 :
2120  FOR FR = LF TO HF STEP FI: REM  FR=Freq LF=Low Freq HF=High Freq FI=
      Freq Increment
2130 FR$ = "FR" +  STR$ (FR): REM  "FR"-HP Instruction for Spot Freq
2140  PRINT D$;"PR#";SL: REM  ENABLE OUTPUT TO IEEE
2150  PRINT D$;"IN#";SL: REM  ENABLE INPUT FROM IEEE
2160  PRINT "RA": REM REMOTE ENABLE
2170 DA = 17: REM
2180 DL$ =  CHR$ (32 + DA):DT$ =  CHR$ (64 + DA): REM  HP MULTIMETER LISTE
      N & TALK ADDRS
2210  PRINT "WT";DL$;T$;"C3": REM  C3=Circuit Mode Parallel
2220  PRINT "WT";DL$;T$;"A2": REM  A2=R/G
2230  PRINT "WT";DL$;T$;"B1": REM  B1=Theta
2240  PRINT "WT";DL$;T$;"T2": REM  T2=External Trigger
```

```
2250  PRINT "WT";DL$;T$;"F0": REM  F0=Data Output Format A/B
2260  PRINT "WT";DL$;T$;FR$;"EN": REM  SPOT FREQUENCY
2280  PRINT "WT";DL$;T$;"EX": REM EXECUTE TRIGGER
2290  PRINT "RD";DT$;T$;: REM   READ HP OUTPUT IN TALK MODE
2300  INPUT A$,B$: REM  INTO TWO STRINGS AS HP SENDS DATA WITH A COMMA SEP
     ARATING THE TWO DATA STRINGS
2310 D(I + 1) =  VAL ( RIGHT$ (A$,11)):D(I + 2) =  VAL ( RIGHT$ (B$,11))
2320 I = I + 2
2330  PRINT "UT": REM  CLEAR HPTALK
2340  PRINT D$;"PR#0": PRINT D$;"IN#0"
2350  HOME : VTAB 10: PRINT "DISPLAY A = "; RIGHT$ (A$,11): PRINT "DISPLAY
      B = "; RIGHT$ (B$,11)
2360  IF FR > HF THEN  POP : GOTO 440
2370  NEXT
2380  RETURN
2390 :
2400 :
2410  REM  *** ERROR ROUTINES ***
2420 :
2430 :
2440  PRINT BL$:ER =  PEEK (222): IF ER = 11 THEN  GOTO 2530
2450  IF ER < 4 OR ER > 9 THEN  PRINT "ERROR: "ER" IN LINE: " PEEK (218) +
     256 *  PEEK (219): END
2460  ON ER - 3 GOTO 2470,2480,2490,2500,2510,2520
2470  PRINT : INVERSE : PRINT "DISC WRITE PROTECTED": GOTO 2540
2480  PRINT : INVERSE : PRINT "END OF DATA ": GOTO 2540
2490  PRINT : INVERSE : PRINT "FILE NOT FOUND": GOTO 2540
2500  PRINT : INVERSE : PRINT "WRONG FILE TYPE ": GOTO 2540
2510  PRINT : INVERSE : PRINT "DISC I/O ERROR: CHECK DRIVE ": GOTO 2540
2520  PRINT : INVERSE : PRINT "DISC FULL ": GOTO 2540
2530  PRINT : INVERSE : PRINT "ILLEGAL FILE NAME "
2540  NORMAL
2550 FI$ = "": GOTO 520
2560  REM
2570  IF  PEEK (222) <  > 49 THEN 2440
2580  PRINT  PEEK (222)
2590 ZZ = 1:IC = 0: HOME : VTAB (12): PRINT BL$"IEEE BUS DISCONNECTED?": PRINT
     : PRINT " ... OR SWITCHED OFF?": VTAB (24): PRINT "HIT RETURN TO CONT
     INUE ";: GET A$: PRINT : RETURN
10000  PR# 1
10010  PRINT  CHR$ (27)"M" CHR$ (9)"80N" CHR$ (27)"N" CHR$ (6) CHR$ (27)"1
     " CHR$ (8)
10020  LIST
10030  PR# 0
10040  END
```

APPENDIX B

Basic Listing of Program CHANGE.DATA.HP

```
10  REM  *** CHANGE.DATA.HP ***
20  REM  ***
30  REM   ********************************************************************************
40  REM   ** THIS ROUTINE WILL TAKE THE REAL/IMAGINARY IMPEDANCE DATA HELD IN  **
50  REM   ** THE .DATA FILES, CONVERT THEM TO /Z/, C, K and D vs Frequency AND **
60  REM   ** WRITE THAT INFORMATION BACK ON THE DISC FOR USE BY THE SCIPLOT    **
70  REM   ** ROUTINE.                                                          **
80  REM   **                      TAW  -  OCTOBER 1984                        **
90  REM   ********************************************************************************

100  DIM D(2000),A$(20)
110 D$ =  CHR$ (4)
120 :
130 :
140  HOME : VTAB 4: HTAB 4: PRINT "SELECT TYPE OF DATA FILE YOU WANT ": PRINT "TO
     PRODUCE FROM THE REAL/IMAG.DATA FILE": PRINT : PRINT : HTAB 12: PRINT "1. /Z/
        vs Frequency": HTAB 12: PRINT "2. C & K vs Frequency": HTAB 12: PRINT "3.
     D     vs Frequency"
150  HTAB 12: PRINT "4. 1-3  Automatically": PRINT : PRINT : HTAB 12: PRINT "5. Di
     splay a File": PRINT : HTAB 12: PRINT "6. END": VTAB 20: HTAB 30: PRINT "WHIC
     H ? ";: GET A$
160  IF  VAL (A$) > 6 THEN 140
170  IF A$ = "6" THEN  END
180  HOME : VTAB 10: PRINT "PLACE DATA DISC IN DRIVE 2"
190  VTAB 20: PRINT "CATALOG DISC (Y/N)? ";: GET AA$: PRINT : REM NEED A PRINT STA
     TEMENT AFTER THIS 'GET' FOR THE 'IF'S BELOW TO WORK
200  IF AA$ = "N" THEN 240
210  IF AA$ = "Y" THEN 230
220  GOTO 190
230  PRINT D$;"CATALOG,D2": PRINT : PRINT : PRINT : PRINT
240  VTAB 22: PRINT "ENTER FULL FILENAME";: INVERSE : PRINT ".DATA.ZCKD/FR.HP": NORMAL
     : PRINT : HTAB 7: PRINT "... NEED THE ";: INVERSE : PRINT ".EXTENSIONS ":: NORMAL
     : PRINT : PRINT : INPUT "FILE: ";FI$
250  PRINT D$;"OPEN";FI$;",D2"
260  PRINT D$;"READ";FI$
270  INPUT D(0): REM  Number of data points in file
280  FOR I = 1 TO D(0): INPUT D(I): NEXT
290  PRINT D$;"CLOSE";FI$
300 LF = D(I - 2):FI = D(I - 1): REM I is pointing to one beyond end of file - hen
     ce these array subscripts for the penultimate and last datum
310  IF A$ = "1" THEN  GOSUB 1000
320  IF A$ = "2" THEN  GOSUB 2000
330  IF A$ = "3" THEN  GOSUB 3000
340  IF A$ = "4" THEN  GOTO 1000
350  IF A$ = "5" THEN  GOSUB 4000
360  GOTO 140
1000 :
1010  REM  *** CONVERT REAL/IMAGINARY IMPEDANCE DATA TO /Z/ vs FREQUENCY ***
1020 :
1030  PRINT D$;"OPEN";FI$;".Z/FR.HP"
1040  PRINT D$;"WRITE";FI$;".Z/FR.HP"
1050  PRINT D(0) - 2: REM  AVOID LF & FI VALUES ON RE-READING
1060 N = 0
1070  FOR I = 1 TO D(0) STEP 2
1080  PRINT LF + N * FI: REM Frequency
1090  PRINT 1 /  SQR (D(I) ^ 2 + D(I + 1) ^ 2): REM /Z/
1100 N = N + 1: NEXT
1110  PRINT D$;"CLOSE";FI$;".Z/FR.HP"
```

```
1120  IF A$ = "4" THEN 2010
1130  RETURN
2000 :
2010  REM  *** CONVERT REAL/IMAGINARY IMPEDANCE DATA TO C & K vs FREQUENCY ***
2020 :
2030  PRINT D$;"OPEN";FI$;".C/FR.HP"
2040  PRINT D$;"WRITE";FI$;".C/FR.HP"
2050  PRINT D(0) - 2
2060 N = 0
2070 P2 = 6.2831852
2080  FOR I = 1 TO D(0) STEP 2
2090 FR = LF + N * FI: REM  Frequency
2100  PRINT FR
2110  PRINT 1E9 * D(I + 1) / P2 * FR
2120 N = N + 1: NEXT
2130  PRINT D$;"CLOSE";FI$;".C/FR.HP"
2140 :
2150  REM *** Calculation of K vs Frequency ***
2160 :
2162 L =  LEN (FI$):FI$ =  LEFT$ (FI$,L - 5): REM CONVERTS FI$.DATA TO FI$ FOR USE
     IN LINE 2170 AS FI$.ID
2170  PRINT D$;"OPEN";FI$;".ID,D2"
2180  PRINT D$;"READ";FI$;".ID"
2190  FOR I = 1 TO 11
2200  INPUT A$(I)
2210  NEXT I
2220  PRINT D$;"CLOSE";FI$;".ID"
2225 FI$ = FI$ + ".DATA": REM  CONVERTS FI$ TO FI$.DATA FOR SUBSEQUENT CALCULATION
    S
2230  PRINT D$;"OPEN";FI$;".K/FR.HP"
2240  PRINT D$;"WRITE";FI$;".K/FR.HP"
2250  PRINT D(0) - 2
2260 N = 0:P2 = 6.2831852
2270  FOR I = 1 TO D(0) STEP 2
2280 FR = LF + N * FI: REM Frequency
2290  PRINT FR
2300  PRINT 14.38 * ( VAL (A$(3)) / ( VAL ((A$(2))) ^ 2)) * (D(I + 1) / (P2 * FR))
    : REM  Dielectric Constant K
2310 N = N + 1: NEXT
2320  PRINT D$;"CLOSE";FI$;".K/FR.HP"
2330  IF A$ = "4" THEN 3010
2340  RETURN
3000 :
3010  REM  *** CONVERT REAL/IMAGINARY IMPEDANCE DATA TO D vs FREQUENCY ***
3020 :
3030  PRINT D$;"OPEN";FI$;".D/FR.HP"
3040  PRINT D$;"WRITE";FI$;".D/FR.HP"
3050  PRINT D(0) - 2
3060 N = 0
3070  FOR I = 1 TO D(0) STEP 2
3080  PRINT LF + N * FI
3090  PRINT  ABS (D(I) / D(I + 1))
3100 N = N + 1: NEXT
3110  PRINT D$;"CLOSE";FI$;".D/FR.HP"
3120  IF A$ = "4" THEN 3140
3130  RETURN
3140  GOTO 140
4000 :
4010  REM  *** READ FILES FROM DISC AND DISPLAY ***
4020 :
```

```
4030  HOME : VTAB 5: PRINT "THERE ARE "D(0);" DATA POINTS IN THE FILE ": PRINT "'"
     ;FI$;"'";" NOW LOADED IN MEMORY": VTAB 10: HTAB 10: PRINT "CAN OUTPUT TO": PRINT
     : HTAB 15: PRINT "1. SCREEN": HTAB 15: PRINT "2. PRINTER": HTAB 15: PRINT "3.
      RETURN TO MAIN MENU"
4040  VTAB 24: HTAB 15: PRINT "WHICH ? ";: GET A$: PRINT
4050  IF A$ = "1" THEN 4110
4060  IF A$ = "2" THEN 4090
4070  IF A$ = "3" THEN  POP : GOTO 140
4080  GOTO 4030
4090  PRINT D$;"PR#1"
4100  PRINT  CHR$ (27)"M" CHR$ (9)"96N" CHR$ (27)"N" CHR$ (6): REM   Print 96 colu
     mns with SOP on RX-80
4110  HOME : PRINT "   FILENAME: ";FI$: PRINT
4120  PRINT "I";: HTAB (12): PRINT "D(I)";: HTAB (24): PRINT "D(I+1)"
4130  FOR I = 1 TO D(0) STEP 2: PRINT I;: HTAB (12): PRINT D(I);: HTAB (24): PRINT
     D(I + 1): NEXT
4140  PRINT D$;"PR#0"
4150  PRINT : VTAB 24: PRINT "HIT ANY KEY TO CONTINUE ";: GET A$: PRINT
4160  RETURN
10000  PRINT  CHR$ (4)"PR#1"
10010  PRINT  CHR$ (27)"M" CHR$ (9)"88N" CHR$ (27)"N" CHR$ (6) CHR$ (27)"1" CHR$ (
     5): REM     Print 88 columns with SOP on RX-80 and LHS margin at 5th col
10020  LIST
10030  PRINT  CHR$ (4)"PR#0"
10040  END
```

APPENDIX C

Basic Listing of Program MAX/MIN/Z/.HP

```
10  REM  ***  MAX/MIN/Z/.HP  ***
20 :
30 :
40  REM  ************************************************************************
50  REM  **                        ARRAY SEARCH ROUTINE                        **
60  REM  **                                                                    **
70  REM  **  THIS  ROUTINE SEARCHES A SINGLE DIMENSIONAL ARRAY [TEMP(*)]       **
80  REM  **  WHICH CONTAINS ALL THE VALUES OF IMPEDANCE /Z/ AT A CONSTANT      **
90  REM  **  INCREMENT OF FREQUENCY. IT IS ASSUMED THAT THE DATA CONTAINS      **
91  REM  **  SHARP RESONANCES  & SPIKES(NOISE).                                **
92  REM  **  TO ENHANCE  THE  PEAKS FROM RANDOM NOISE, THE LOG OF /Z/ vs       **
93  REM  **  FREQUENCY IS OBTAINED (L#392) AND  SCANNED FOR MAX & MINIMA       **
100  REM **  BY FINDING IF THE CURVE IS NEGATIVE OR POSITIVE GOING AS THE      **
110  REM **  POINTER MOVES INCREMENTALLY DOWN TEMP(*).  IT ASSUMES THAT        **
120  REM **  WHEN THE CURVE CHANGES FROM +VE TO -VE OR -VE TO +VE SLOPE        **
130  REM **  THAT A MINIMUM OR A MAXIMUM HAS BEEN FOUND - HENCE IT NOTES       **
140  REM **  THE POINTER # OF TEMP(*) INTO ARRAY P(*).  P(*) ARRAY HAS         **
150  REM **  BOTH REAL AND SPURIOUS DATA (NOISE).                              **
160  REM **  FINALLY, AN ATTEMPT IS MADE TO DISCRIMINATE THE NOISE AND THE     **
170  REM **  DATA BY EXAMINING THE SLOPE OF THE DATA IN TEMP(*)  AT THE        **
180  REM **  MAXIMA & MINIMA BY EXAMINING THE SLOPE BETWEEN THE MAX/MIN        **
190  REM **  AND +5 AND -5 DATA POINTS - ONLY THOSE POINTS HAVING A SLOPE      **
200  REM **  GREATER  THAN  AN  ARBITARY  VALUE ENTERED BY THE USER  ARE       **
210  REM **  ACCEPTED AND PRINTED OUT.                                         **
240  REM **                                                                    **
260  REM **                            TAW  -  SEPTEMBER 1985                  **
270  REM ************************************************************************
280 :
290 :
300  REM  CHANGE=INC OF Y VALUE,FI$=FILE COLOR= NAME,N=COUNTER (1=1ST MIN,2=1ST MA
     X,3=2ND MIN ..),P=POINTER,P(*) POINTER ARRAY,TEMP(0)=TOTAL POINTS IN FILE,TEM
     P(*)=DATA ARRAY,FI=X FREQ. INCREMENTS,LF=LOWEST(START) FREQUENCY
310 :
320 :
330  DIM TEMP(2000),P(30),PA(30)
340 :
350  HOME : VTAB 2: PRINT "THIS ROUTINE WILL SEARCH THE /Z/ FILE": PRINT "NAMED BE
     LOW FOR THE FREQUENCY VALUES": PRINT "AT WHICH MAX/MIN VALUES OF /Z/ OCCUR"
360  VTAB 6: PRINT "PLACE DISC IN DRIVE 2": VTAB 10: INPUT "CATALOG DRIVE 2? (Y/N)
     ";A$: IF A$ = "N" THEN 366
362 D$ =  CHR$ (4): PRINT D$"CATALOG,D2"
364  IF A$ <  > "Y" THEN 360
366  PRINT : PRINT : INPUT "ENTER FULL FILENAME ";FI$
370  PRINT D$"OPEN"FI$",D2": PRINT D$"READ"FI$
371  INPUT TEMP(0),LF,TEMP(1),FI:FI = FI - LF
375 LAST = TEMP(0) / 2
380  FOR I = 2 TO LAST: INPUT TEMP(I),X: NEXT : REM   X=DUMMY TO ALLOW READING OF
     ALTERNATE ENTRIES IN SEQUENTIAL FILE.
390  PRINT : PRINT "CHANGING ARRAY DATA TO LOG (DATA)"
392  FOR I = 1 TO LAST:TEMP(I) =  LOG (TEMP(I)): NEXT
400  PRINT D$;"CLOSE"
410 :
420  REM  *** SEARCH TEMP(*) ARRAY FOR MAX & MIN VALUES ***
430 :
435  PRINT : PRINT "SEARCHING FOR ALL MAX.MIN /Z/ VALUES"
440  FOR I = 1 TO LAST
450  IF TEMP(I) - TEMP(I + 1) >  = 0 GOTO 510: REM - NEGATIVE GOING CURVE
460  IF FLAG = 1 GOTO 560
```

```
470  IF N = 0 THEN N = 1
480 P(N) = I: REM -  ARRAY POINTER FOR MINIMUM
490 N = N + 1
500 FLAG = 1: REM - SET FLAG AFTER PASSED MINIMUM
510  IF FLAG = 0 GOTO 560: REM - NEG GOING AND BEFORE A MINIMUM
520  IF TEMP(I) - TEMP(I + 1) <  = 0 GOTO 560: REM  - POSITIVE GOING CURVE
530 P(N) = I: REM - ARRAY POINTER FOR MAXIMA
540 N = N + 1
550 FLAG = 0: REM - RESET FOR NEXT MINIMUM
560  NEXT
570 :
580  REM  *** DISCRIMINATE SHARP PEAKS AND VALLEYS ***
590  REM  *** FIND SLOPE OF THE CURVE AT EACH SIDE ***
600  REM  *** OF A MAX OR MIN - +/- 5 ARRAY POINTS.***
610  REM  *** IF > 'SLOPE' THEN KEEP ARRAY #  > F A  ***
108  REM  *** MINIMUM IN ARRAY PA(*)                ***
630 :
640  HOME : VTAB 10: INPUT "WHAT SLOPE DO YOU WANT (TYPICALLY 0.02 TO 0.2) ";SLOPE

650  HOME : VTAB 10: INPUT "OUTPUT TO SCREEN OR PRINTER (S/P) ";A$: IF A$ = "P" THEN
     670
660  IF A$ = "S" THEN 715
670  PRINT  CHR$ (4);"PR#1"
680  PRINT  CHR$ (9); CHR$ (1): REM  REASSIGN CHR$(9) TO CHR$(1)
690  PRINT  CHR$ (27)"M"; CHR$ (1)"80N"; CHR$ (27)"N" CHR$ (6): REM   ELITE SCRIPT
      FULL WIDTH WITH A 6-LINE SKIP-OVER PERF ON EPSON RX OR FX PRINTERS
700  PRINT  CHR$ (27);"e"; CHR$ (0); CHR$ (12);: REM  SET TAB STOPS EVERY 12 SPACE
     S FOR RX-80 p37
710 HT$ =  CHR$ (9): REM  HORIZONTAL TAB KEY
712  GOTO 720
715 HT$ = "    "
720  PRINT "POINTS OF CHANGE OF SLOPE IN TEMP(*)": PRINT
730  PRINT ;HT$;"ARRAY #";HT$;"Freq"
740  FOR I = 1 TO N - 1: PRINT HT$;P(I);HT$;(P(I) - 1) * FI + LF: NEXT
750  FOR Z = 1 TO 19
760 TEMP(P(Z) - 5) =  ABS (TEMP(P(Z) - 5))
770 TEMP(P(Z)) =  ABS (TEMP(P(Z)))
780 TEMP(P(Z) + 5) =  ABS (TEMP(P(Z) + 5))
790  IF ((TEMP(P(Z)) - TEMP(P(Z) - 5)) / FI) AND ((TEMP(P(Z)) - TEMP(P(Z) + 5)) /
     FI) > SLOPE THEN PA(Z) = P(Z): REM FIND MINIMA (+VE #'S)
830  IF Z = 18 THEN 850
840  NEXT
850  PRINT : PRINT : PRINT "FREQUENCIES WHERE A CHANGE OF SIGN IN SLOPE OCCURS"
860  PRINT "AND THE SLOPE IS GREATER THAN ";SLOPE
870  PRINT HT$;"Z";HT$;"Array# Min";HT$;"Array# Max";HT$;"MIN";HT$;"MAX"
880  FOR Z = 1 TO 19
890 MIN = 0:MAX = 0
900  IF PA(Z) <  > 0 THEN  GOSUB 1010: REM AT A MINIMUM
910  GOTO 920
920  NEXT
930  PRINT  CHR$ (4);"PR#0": PRINT
940  HOME : VTAB 10: PRINT "LAST SLOPE WAS ";SLOPE;: INPUT ", TRY ANOTHER (Y/N)? "
     ;A$
950  IF A$ = "N" THEN  END
960  IF A$ <  > "Y" THEN 940
970  HOME : VTAB 10: INPUT "ENTER NEW SLOPE ";SLOPE
980  FOR Z = 0 TO 30:PA(Z) = 0: NEXT : REM  - CLEAR PA(*) BEFORE TRYING A NEW SLOP
     E
990  VTAB 22: PRINT "HIT ANY KEY TO CONTINUE ": GET A$
1000  GOTO 650
```

```
1010 :
1020  REM  *** OUTPUT MIN & MAX FREQUENCIES ***
1030 :
1040 MIN = (P(Z - 1) - 1) * FI + LF
1050 MAX = (P(Z) - 1) * FI + LF
1060  PRINT HT$;Z;HT$;P(Z);HT$;P(Z + 1);HT$;MIN;HT$;MAX
1198  RETURN
10000  PRINT  CHR$ (4)"PR#1"
10020  PRINT  CHR$ (27)"M" CHR$ (9)"88N" CHR$ (27)"N" CHR$ (6) CHR$ (27)"1" CHR$ (
     5): REM  Print 88 columns with SOP on RX-80 and LHS margin at 5th column
10030  LIST
10040  PRINT  CHR$ (4)"PR#0"
10050  END
```